

## CENTRAL INTELLIGENCE AGENCY

## INFORMATION REPORT

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INTRODUCTION

1. During the summer of 1946, at the Raabe Institute, the Soviet administration, composed of General Geydikov and Colonel Korolov, issued an order for the further development of the A-4. The objective was to materially increase the performance of the A-4. The details of this

USAF, DIA, review completed.

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order were not known [ ] Upon the arrival of the group in the Soviet Union, the Ministry of Armaments issued a similar order for the further development of the A-4. [ ]

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[ ] the order established only general requirements. The basic requirement called for a range of approximately 700 kilometers while delivering a 1,000-kilogram explosive with possibly improved accuracy of fire.

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2. This order established the R-10 project [ ]

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[ ] The R-10 might be [ ] to which the Germans were assigned for a period ranging from the fall of 1946 to the spring of 1949. Those involved in the work represented a diverse group with varying amounts of experience. [ ]

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3. First of all, only a few technicians from the original and principal missile development site in Peenemuende were represented. The few that were present had not held positions in Peenemuende which would permit them a deeper insight into the overall program. The Peenemuende specialists could offer little experience which might serve to give direction to the development work.

4. Another group of specialists was composed of the so-called "firing men", who had had military experience in the actual fitting of the A-4. The technical training of members of this group was partially incomplete. Though they may have had firing experience, development pointers could hardly be expected from this group.

5. A group of mathematicians working in the ballistic department under the direction of Dr. WOLFF (formerly chief ballistic expert at KRUPP) was thoroughly equipped to solve basic questions and engage in development work. Particularly, WOLFF's deputy, Werner MUELLER, possessed the ability to comprehend the practical development stages, as well as the ability to solve these problems mathematically.

6. Questions in aerodynamics, especially in the supersonic field, were dealt with primarily by Dr. ALBRING, chief of the aerodynamic department. Vast knowledge in aerodynamics, an optimistic outlook, and a creative talent permitted ALBRING to make many contributions in the development work.

7. The thermodynamics department led by Dr. UMPFENBACH worked on the propulsion unit. This department had several good scientists capable of solving theoretical questions. Creative talents, however, could hardly be found in this section.

8. The controls were in the hands of Dr. HOCH, a competent and even creative professional, though he was of unreliable character and was an informant.

9. Radio was primarily in the hands of the creatively talented practitioner PREIKSCHAT [ ] and the theoretician Dr. MOLLWO.

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10. The design and stress department was essentially composed of development men from the former ARADO Airplane Plant. These men were thoroughly capable of carrying out new development work. The design work was performed under the leadership of Dipl. Ing. BLASS and his deputy, Ing. ANDERS.

11. The stress section, under Dipl. Ing. and Dipl. Math. Rudolf MUELLER [redacted] was responsible for all questions of structural design and stress analysis. [redacted]

12. As can be seen from the above, it was hardly possible to base the development work on the A-4 experiences of the Peenemuende representatives. Scientists and engineers coming from the most diverse fields had to give the impetus for the development work. Development carried out with this type of human material was a risky venture and doubly so since experimentation was non-existent.

13. During the course of development, many channels and possibilities were explored theoretically and numerous draft reports were submitted. The final product of the R-10 projects was a voluminous report containing the complete design of the missile. This report was turned over to the Soviets but final disposition was unknown. The entire project was a "paper project" with no parts being constructed at Gorodomlya Island. Whether or not the R-10 missile was constructed by the Soviets was never discovered by the Germans.

FUNDAMENTAL CONCEPTS UNDERLYING THE DEVELOPMENT OF THE R-10

14. The drawings of the A-4 (V-2) were available to serve as basic data for the German group. [redacted] calculations which could have given more detailed insight into the interrelations of the A-4, were completely missing. Only those calculations which had been newly compiled in Germany during 1946 and again in the early days in the Soviet Union were available. How incomplete and unreliable the newly compiled calculations were is readily conceived when one recalls the few and loose directions which were given to the German specialists.

15. The given requirements were to be achieved under no circumstances by simply making minor changes in the A-4. Consequently, a systematic new development on a mathematical-physical-technical basis became necessary. Experiments were not possible, except on a very modest scope and primarily only in the fields of controls and radio. All reference points used during the design stage were obtained from the calculations performed during the theoretical phase.

16. The ensuing development work took the form of very close coordination between the various departments. This coordination took various forms. Thus, for example, it took the form of conferences between the various department chiefs, under the chairmanship of the chief designing engineer, and to which principal experts were invited. At other times, it took the

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form of consultations between a few or several department chiefs or experts.

17. The ballistic calculations showed clearly that two factors were of great importance in reference to the missile's range:
  - a. The specific thrust in kg thrust per kg fuel per second.
  - b. The relationship of the launching weight to the weight at propellant-cut-off.
18. For this missile there appeared to be little chance of improving the aerodynamic drag and so the drag factor moved into the background in regard to the two aforementioned factors.
19. As far as point (a) was concerned, an increase of the specific thrust could be achieved by means of different reaction materials (fuels), increased combustion pressure, and/or more efficient combustion. The absence of any experimental possibilities seemed to make a study along these lines either impossible or too daring. Therefore, a material improvement of the specific thrust for the development of the A-4 had to be dismissed at that time.
20. Increasing the ratio of the launching weight to the weight at propellant-cut-off could be achieved by:
  - a. Improving the air frame (cell structure design).
  - b. Increasing the absolute launching weight while using the same combustion chamber. That is, by means of decreasing the relationship of rocket thrust to launching weight.
  - c. Carrying out thorough weight economies in all other parts of the missile, particularly in equipment, control mechanisms, and auxiliary drives of the combustion chamber.
  - d. Improving the arrangement of the mixture ratio; that is, by decreasing the residual fuel in the containers, fuel lines, and the combustion chamber.
  - e. Providing for a system in which the warhead could be separated from the airframe.
  - f. Providing for a multiple-stage construction of the missile.
21. The following discussion represents my recollections of the thought process and the problems involved in the handling of the above six steps as associated with the R-10.

#### Improving the Airframe

22. In order to execute the required stress analysis on the A-4, it was necessary to make so-called load assumptions (lastenan-nahmen). It was necessary to find for every structural part the stress or at least the ideal stress which would affect that part most unfavorably. Such load assumptions were readily made using the available data resulting from weight measurements, calculations of the ballistic path, the aerodynamic calculations, the control force calculations, the rocket thrust, etc. From these "load assumptions" and the resulting stress analysis for the A-4, a series of reference points for the airframe structure were obtained. It was revealed that the transverse load and the

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resulting bending stress, two factors which are of primary importance in airplane design, were relatively unimportant to the missile. It was found that decisive for the rocket were primarily stresses arising from the longitudinal forces and the surface pressures resulting from the air flow. Although bending moments were present, they were considered of secondary importance in the structure.

23. In the course of the development it was shown more and more that thermic stresses entered into the problem. These would arise from the very low temperature of the liquid oxygen (approximately  $-183^{\circ}\text{C}$ ) and also from the possibly very high surface temperatures which would develop from the friction of air on the surface at very great speeds.

24. When the structure of the A-4 was regarded from these points of view, many things appeared illogical. Foremost, the greatest section of the missile, the central section, was apparently designed incorrectly. To clarify this point a short dissertation was presented [redacted] on the already well-known structure of the A-4. Two welded light metal containers (the front one for the reception of the alcohol, and the rear one for the reception of the liquid oxygen) which for technical reasons were placed under a certain amount of pressure, were attached at a few points to the outer shell. Between the containers and the outer shell was a thermal insulation composed of glass wool. All longitudinal stresses, bending moments, and pressures acting on the outer shell had to be absorbed by the shell structure. The outer shell, made completely of steel, was reinforced by means of a stringer and former network. The many connecting points at the missile head and at the tail, as well as the many flaps, pointed to a very inferior stage of development in the structure. These circumstances gave rise to the inference that many imperfections were to be found in the remaining basic structural designs.

25. This two-case structural design was bound to be not only expensive to construct but also added a great deal of weight. It further resulted in a diminution of the tanks' contents because of the inevitable reduction in dimensions.

26. Because of the above shortcomings, a single shell structure was considered and found to have many advantages over the old A-4 structure. The following consideration led to this conclusion. For technical reasons the tanks must be constantly subjected to a certain pressure. This is particularly important in regard to the liquid oxygen, as the latter is very close to the boiling point and since the boiling point is raised as a result of an increased pressure. A boiling liquid is difficult to convey in exact quantities and causes a great cavitation danger for the pumps.

27. A circular container under continuous pressure produces tensile stresses on the container walls which are two times as great in the circular direction as in the longitudinal direction. However, the tensile stress is that stress which will support the greatest values in a thin-walled structure. Such a structural design results in the lowest expenditure of material and, consequently, the least weight as well.

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28. To be considered then was the relationship existing between such a structure which would produce pressure from within and yet must absorb outer forces, that is, the longitudinal forces, the bending moments, and the outer pressures upon the surface. The pressure and longitudinal forces acting on the missile must decrease the tension and longitudinal forces produced from within the tanks. Should these compressive and longitudinal forces become greater than the tensile forces and longitudinal forces, a compressive force would result which up to a certain point (that is, the buckling forces of the cylindrical shell) could be absorbed.
29. The bending moments of the missile would produce tensile and compressive stresses. The tensile stresses would increase the already existing tensile strength coming from the internal pressure. This was found to be permissible without increasing the wall thickness since the longitudinal tensile stresses arising from the inner pressure would be only one-half as great as the circular tensile stresses. Concerning the compressive stress and bending stresses nothing more need be said, since the same considerations apply that were discussed above in regard to the compressive and longitudinal forces.
30. Another problem considered was the result of the forces because of the flow of air over the missile. The flow of air would produce pressures positive or negative depending on the position along the longitudinal axis. When the angle of incidence is zero degrees, the forces would be equally distributed around the circumference and either added to or subtracted from the internal pressure. The magnitude of these forces are small compared to the internal forces and thus have little effect. In the case of the A-4, the surface forces on the outer skin were not absorbed by the larger internal pressures and thus were of such magnitude as to cause skin deformation and additional stress in the spars.
31. Should the missile be flown at an angle of incidence, a somewhat sine-shaped pressure distribution around the cross-section of the rocket would result. Since these pressures are, however, always small in relation to the internal pressure, a minute deviation from the round form that might result would lead to a new state of equilibrium resulting from the internal pressure. During the course of construction or during ground handling, internal pressure would not be present for stability and so light ribs were provided for in the design. These ribs were to be placed at intervals of approximately 800 mm. These ribs could, in addition, contribute greatly to maintaining the round form, and thus be more receptive to the air forces, which have already been described.
32. During the transportation of the missile from the factory in the Meilerwagen (specially constructed transport carriage) on the street, as well as during the mounting on the launching table, sufficient stability must be provided for the container central part, even without internal pressure. It was found that by means of an intelligently placed support for the missile, it would be possible to keep the forces and moments very small and that sufficient stability for all practical purposes on the ground could be maintained.

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33. It was found further that the structural design of a circular unbraced cylindrical shell had a certain buckling strength during flight even without internal pressure, providing only the ascending part of the flight was considered.

34. Another problem of concern was the factors involved due to thermal conditions. Since liquid oxygen has a temperature of  $-183^{\circ}\text{C}$ , there would result at normal outside temperature, a very great temperature difference between the air and the container wall. If, by means of an opened valve, the container was vented, then the container pressure could not rise above the outside pressure. The total amount of heat absorbed would then be dissipated in evaporating the oxygen, and the liquid oxygen would remain at essentially the same temperature.

35. Immediately before launching, the oxygen tank must be placed under pressure. As a result, the boiling point of the liquid oxygen would be raised. Before the oxygen may be brought to the boiling point it is necessary to supply sufficient heat to the entire liquid and only then would all additionally added heat be used for the vaporization. (If the heat supply on the walls is very intense, the boiling temperature will be reached at the walls while the liquid within the interior of the container hardly changes, resulting, therefore, in local vaporization along the container walls.) During the ascending part of the flight, heat is naturally supplied, because of 1) greater flow speeds, 2) the increasing temperature difference, since a great increase of the boundary layer temperature appears at high speeds (proportionately with the square of the speed). When the main speed acceleration occurs at great heights, the transmitted heat quantities are, however, minute since the air density enters proportionately into the transmitted heat quantities. These heat transfer characteristics were taken into consideration based on the possible R-10 dimensions. They were calculated by excellent heat specialists for later development purposes. The temperature rises of the liquid oxygen, as well as the local vaporization along the walls, remained within absolutely tolerable limits throughout the required time. As the oxygen container already would be subjected to pressure by means of gaseous oxygen, it remains important only from the standpoint of the gas-producing unit to determine how much gaseous oxygen would be formed along the container's walls and how much in the gas-producing unit itself.

36. Some deliberations were made on matters concerning the thickness of the frost layer which could settle for a time while the fully tanked missile would be standing and the layer of ice which could settle during rainy weather. The aerodynamic impediments, as well as the additional weight, were found to be insignificant. It was felt that all this would soon melt in the course of the ascent because of the considerable boundary layer temperature developed.

37. All calculations pointed to the fact that no critical circumstances or other unpleasant considerations could be found which worked against the selection of the one-container structure for liquid oxygen.

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38. In the case of the alcohol container, the circumstances were much more advantageous since the alcohol would be at approximately normal temperature, and thus the formation of frost or ice would be completely out of the question. Further, since there would be a much greater difference between the normal temperature and the boiling temperature as in the case of the liquid oxygen, there would not exist any cavitation danger for the fuel pumps.

39. In order to lose as little space as possible for fuel in such a one-container structure, the two containers were separated only by a partition with oxygen in the lower portion of the container and alcohol in the upper. Since the two liquids would have a temperature difference of approximately 200° centigrade, there would occur as a result heat-conduction along the walls and also, as a result of radiation, a certain interchange of heat between the two liquids in the vicinity of the partition. This, however, would be practically confined to the pre-launching waiting period of the fully tanked missile. Since the liquid oxygen would not come in contact with the partition, the layer of gaseous oxygen in the condition of equilibrium, which would rest over the liquid oxygen, would form a good insulator. The alcohol immediately above this layer and along the partition would be in a state of equilibrium during this period as well as during the cooling process. Due to the fact that the pure heat condition of the liquids is very low, there would occur locally, nevertheless, a noticeable cooling of the alcohol. The danger of a local freezing of the alcohol, however, would not exist. Consequently, in the course of the later development work the originally planned insulation of the partition was dispensed with.

40. Of importance and worthy of mention is the selection procedure of material used in the central part (containers) of the missile. The containers must be impermeable to gas and liquids. Therefore, and in view of the thin wall dimension, a rivet construction was immediately dismissed as impracticable and a welded construction was chosen.

41. Most construction steels become very brittle at low temperatures (-183° C), that is, they have a very low notch-impact strength. Therefore, steel was at least momentarily dismissed. If made of steel, the wall thickness would have only 1/3 the wall thickness of a light metal (alloy) of equal weight. This would result in a very thin wall dimension for the outer shell, which would have a great surface sensitivity and a lower buckling strength.

42. At that time the light alloy  $AlMg_3$  was pointed out to the Germans as having excellent welding characteristics and at the same time as being easily procurable. A major disadvantage of this alloy was its low tensile strength and particularly its low elastic limit of approximately 8 kg/mm<sup>2</sup>. For certain connecting parts, such as the front and rear connecting ribs, a similar light metal alloy was used. The low tensile strength values of the materials led to relatively large dimensions. Nevertheless, there resulted a considerable weight saving.

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43. From the selected form of the missile (approximately the same contours as the A-4) and from the ballistic path, considerably high surface temperatures, particularly in the forward container, could be calculated. [ ] temperatures of approximately 340°C in the 2.55 mm outer shell were obtained through calculations. Naturally, at such temperatures the alloy's tensile strength decreased considerably.

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44. Reference must be made to another matter in line with this development. In the A-4, there were distributed over the missile's entire body many flaps and access panels. Several of the old "Peenemuende" specialists thought that these parts had frequently been the cause of mishaps. The design of these parts would make this theory very plausible. Therefore, during the new development, care was taken to eliminate these parts entirely or at any rate to restrict the number as much as possible. Thus, there was not a single outside opening flap on the entire central section of the missile. In the warhead, [ ] one or two flaps were placed with a great deal of extra attention being given to their safe design. The connecting points between the warhead and the central section, as well as the connecting points between the tail and the central section of the missile, were so designed as to make unnecessary additional cover plates. [Further particulars concerning the design are given in a later section.]

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45. The old A-4 construction was characterized by its shell construction, which was made of steel sheets with tight rib and stringer paneling. The stringers were continuous, thus cutting through the ribs and as a result weakening the latter. These ribs were greatly strained as they had to transmit the bending moments from the tail controls. Because of the shell design, many connections were provided for the connection of the trunk to the central section of the missile. This type of connection must be regarded as statically too intricate and too difficult for construction. Conspicuously difficult and intricate was the final rib of the tail cone, a piece of light cast metal. The tail controls also were made of steel and had the important structural task of transmitting all the forces of the fully tanked missile while rested, prior to launching, on the so-called "launching table".

46. In order to economize on weight, to make the design less complex and clearer, basically different force paths had to be considered for the R-10. The greatest forces for the rear section came from the fin and rudder with their airloads and the longitudinal forces derived from the mounting of the missile on the launching table. It appeared, therefore, advantageous not to conduct these longitudinal forces into the tail section shell and then to the central section of the missile by way of the many connecting points. The simplest way was to conduct these forces directly from the fins to the central section of the missile at these four points. Should the fins not reach the central sections connection, then the forces would pass over the immediate continuation of the four connecting points, the out-rigging, longitudinal forces and bending moments from the tail section cone would then also be carried by the out-rigging.

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From these considerations resulted a simple 4-point connection of the tail to the central section of the missile. Further ribs or out-riggings for the tail were no longer necessary. The tail ribs were uninterrupted, and not weakened, by stringers that cut through them.

47. The end rib in the tail was designed as a simple U-shaped rib. It served at the same time as support for the motor nozzle, so that no great strain would be placed on the propulsion unit as a result of transverse loads acting through the thrust frame. Since the forces from the propulsion unit would be opposite generally to the air loads of the tail unit, the result was a force equilibrium and an easier arrangement.

48. The jet fins and their bearings and the rudder mechanism were stored in a welded steel box, which was mounted to the strong end rib and the tail unit spar. Through this measure a simple, firm, and neat grouping for these parts was achieved.

49. The original aerodynamic thinking was that suction or a negative pressure would act on the outer skin of the tail section as long as a good seal could be maintained between the nozzle and the end rib. However, later, [redacted]

[redacted] results of lift and pressure distribution measurements under various Mach numbers were published for the A-4. These results showed a rather complicated distribution on the tail during initial firing under angles of incidence. From the stress point of view a pressure was needed acting internally on the skin. It was thought that this could be achieved through ventilation, but the lack of aerodynamic data prevented a solution. Because of this and the leaking of the tail, the stress analysis became uncertain and the problem was left for solution at a later time when firing tests could be made.

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50. The material decided upon for the tail section was to be a high grade alloy rather than steel. Disregarding temperature requirements, this material would be advantageous in construction and in relation to the all important weight and range consideration. The material was an alloy similar to dural. The heating of the outer covering in the tail section would be very high and so the strength would decrease rapidly. This, however, did not affect the material selection, since the highest demands on the outer covering would appear at a time when the surface temperature would still be low. At the time of greatest heating, that is at propellant cut-off, the stress demands on the tail section would be small. This also applied even to a higher degree to the tail unit covering.

51. Before the development of the warhead is discussed, a short description of the known design of the A-4 warhead should be given. In the A-4, explosives were simply placed in a thick steel shell, which was closed by a fairly thick steel door. The outer form was the front part of the ogive of the missile. No separation between the warhead and the rest of the missile took place after the propellant cut-off and so the only stability considerations were for the entire missile. A separation of the warhead from the rest of the missile was called for in the new development of the R-10. [This shall be discussed in more detail further

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in this section. / During the development there were no explosive experts available to lead this project.

52. Since an increase in the explosive had been demanded, a considerable weight increase of the warhead would have resulted in retaining the thick steel shell. Since the weight of a missile is the most critical factor in respect to range, a reduction of the structure weight had to be attempted.
53. A considerable increase in range demands greater velocity (range approximately proportional to the square of the speed) and, therefore, results in an increase in heating. Retaining the wall dimensions of the A-4 would have probably resulted in a dangerous heating of the explosives. Consequently new considerations were involved.
54. The first question was, "Is the thick steel wall necessary for dam up reasons or not?" The Soviets and also the Germans answered, "No". Ignition should take place at a certain distance above the ground. Consequently, a protection of the explosives at impact by a thick shell was unnecessary.
55. Before attacking the design problem, something should be said about stability. The free flying warhead naturally had to be stable, that is, the center of gravity had to be ahead of the center of pressure. Because the outer form was fixed, stability could be achieved in two ways. Either the separation point for the warhead could be at a point far enough to the rear to permit the explosive to provide a forward center of gravity, or the end of the head as provided with appropriate controls. Constructively the first version was preferred, whereby a piece of the missile was simply included as a stabilizing shell.
56. With this in mind, what design could be imagined which would resist the stresses and the high temperatures obtained during descent, and also protect the explosive from undue heating? Two different designs were undertaken. The first was to select a material which could not resist the temperatures for long and was slowly destroyed, for example, burned out. The destruction could not proceed too fast and the material would have to have the smallest possible heat transfer coefficient, so that the heat would reach the still undamaged material as slowly as possible. Through a low heat transfer coefficient, heat protection for the explosive could be achieved at the same time. The expansion of the covering for the explosive would then be negligible and, therefore, the formation of a very undesirable hollow space between explosive and outer covering was not to be feared.
57. A plywood covering, protected by impregnation against direct combustion, appeared to be the right answer. The theoretically very difficult question remained, "How much of the plywood covering would be destroyed?" The plywood covering had to have such thickness that the remaining part had sufficient solidity. It was not possible at the time to make actual tests. The only experiments were those made on plywood with a blowtorch and with autogenous welding apparatus. After burning with the blowtorch (1300°C) for half and also one minute, the results showed

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relatively little destruction of the surface. But with the welding apparatus [redacted] the 10 mm plate was destroyed in 20 seconds. The transferred amount of heat during this time was measured by melting ice blocks, and then compared with the theoretically calculated amount. Such primitive experiments naturally could not lead to satisfactory results, but only served as an indication. Since the actual boundary layer temperatures in descent possibly would be somewhere between the temperatures produced by the blowtorch and the welding apparatus, and also the time in question was possibly a little longer than half a minute, such a construction method seemed possible. Obviously clarification by actual tests were necessary.

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58. Therefore, the thickness of the plywood was then assumed to be 20 mm, and the depth of burning was calculated at 10 mm, leaving a 10 mm wall thickness for support. A 20 mm plywood covering had the same weight, approximately, as a 2 mm steel covering. Since little heat could penetrate inside, the cover would not expand and would fit the explosive. Consequently, the covering would be braced by the explosive and there would be no danger of breakage because of the pressure on the outer covering nor from longitudinal pressures.

59. In the rear, the freely protruding part of the plywood shell would be subjected to longitudinal pressure forces and also to outer pressure. The protruding plywood shell was reinforced by means of a wooden rib. The outer casing of the warhead was mounted on a small ledge of the central section of the missile. There were no further attachments. The union of the two parts was effected solely by means of a spring tension along the center axis of the missile. For this reason, the rear sealing panel in the warhead and also the forward panel of the central section of the missile were given a conic shape. Such a shape (i.e. for the panels) was most favorable for the reception of centrally introduced longitudinal force.

60. By means of the above described structural design, it was possible to lower by a fraction the structural weight of the missile as compared with that of the A-4. For a second method, the Soviet chief engineer KARGANOV demanded the execution of a design utilizing a steel shell as well.

61. As already mentioned, it was unfeasible to use the methods of the A-4 in this connection. The basic considerations and starting points were as follows: To use a shell of heat resisting steel (9.1 T) and dimensionalize it in order that all forces at the existing temperature could be absorbed, a safety factor in the range of 1.5 was essential. Such a strongly heated steel shell naturally would expand considerably in a circular as well as in a longitudinal direction. A direct insertion of the explosive then was out of the question. Consequently, a construction of a second shell for the explosive was necessary. This second shell was to be made of comparatively thin-walled alloyed sheet metal. In order to obviate an overly strong construction of the two shells (particularly the highly strained outer steel shell) supports or braces between the two shells became necessary. These braces, however, had to be constructed in such a manner as to conduct very little heat and to assure constant

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butting in the face of the strong expansion of the outer shell in a circumferential and in a longitudinal direction.

62. Pursuant to the laws of heat transmission, a material was selected which at high temperature would have sufficient stability while at the same time possess a low thermal conductivity. Further, in order to limit the surface affected by the heat transmission, highly alloyed nickel-steel studs were riveted at the support points. The interval between these studs was approximately 40 mm. The resolving linear length for heat conduction of these support studs, because of structural-technical reasons, was unfortunately very low.

63. From the strength of the sheet metal for the outer shell it was possible to calculate the relation of the temperature at the individual points and also the expansion in the circular and longitudinal direction. The transmission of all longitudinal forces between the inner and the outside shell would take place in the forward part of the vortex where the diameter was small. This connecting point was thus the reference point for the longitudinal expansion, since at this place the reciprocal displacement is zero.

64. By placing a conic ring on the inner casing where a brace between the two shells would be desired for stability reasons, the brace studs would then, during every thermal expansion, methodically support these conic rings. The conic ring pitch had to correspond to the ratio of the circular to the longitudinal expansion at this point. (See Pt. 13, page 35.)

65. A further comment is submitted in regard to the heat transmission between the two shells. The heat transmission results through:

- heat conduction through the air gap.
- heat radiation.

66. The amount of heat which can be transmitted by means of an air gap is, of course, small. As this gap was open at the rear of the warhead, a very minimal air density would be available not only at high altitude but at low altitude as well, since a strong suction head would exist behind the rapidly flying warhead. Since the air density enters linearly into the transmitted air mass, the heat conduction would remain very small.

67. The heat transmission through radiation is dependent on the fourth power of the absolute surface temperatures and on the surface constants of the material used as surface. Since the surface temperatures while on the ground would not be material, only a moderate heat transmission would be possible irrespective of time. During take-off the surface temperature would increase markedly, but the available time would be very small. In addition, the light metal surface selected for an inner shell had a very low radiation coefficient.

68. The total transmitted heat quantity was used to heat the inside shell (that is, the light metal surface) and in addition a

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small layer of the adjoining explosive. Since the explosive turns liquid or at least pasty at approximately 70°C, the temperature would have to be kept as far below this point as possible, for the explosive charge entered into the stress calculations as a solid body or support for the two shells.

69. The "stabilization ring" (Stabilisierungs Ring) which extended to the stern and passed over the explosive part was reinforced by means of a steel rib so that it was capable of absorbing the outside air pressure. As this interior rib would remain much colder than the outside shell (skin) considerable thermal stresses would be present. The possibility of introducing a cold rib into the outside shell, while heated to approximately 400°C, in the hope that this pre-stress might improve the operating condition, was considered.

70. The connection of the above-discussed steel warhead with the central section of the missile was, in principle, similar to the plywood warhead which has already been briefly treated.

71. The structural design of the steel shell was rather complex and the structural weight was greater ( [redacted] approximately 70%) than that of the plywood warhead. However, the weight was much less than that of the A-4. 25X1

72. However, one point which repeatedly arose towards the end of the development work should be mentioned here. Conspicuous in this presentation is the fact that in respect to the structural design of the A-4 nearly everything was altered, while the exterior shape of the A-4 remained virtually unchanged. In the early periods, since the aerodynamic department had no experimental opportunities and only very limited literature at its disposal, the department was very handicapped. At the time no clear opinions prevailed as to the advantages that could be gained from changes of the exterior form. In addition, the whole development staff was at the time not sufficiently familiar with the new project. Upon completion of the working drawings and the calculations, it became evident that a simple conic form would be more desirable. However, because of the advanced stage of development of the R-10 and the uncertainty concerning the new exterior shape, the R-10's shape remained that of the A-4 except for a minor increase in the length.

73. This completes the treatment of the development of the air frame's structural design and the various viewpoints held by the German staff in this connection.

#### Ratio of Launching Weight to Rocket Thrust

74. It was in connection with the problem of increase in absolute launching weight that much uncertainty prevailed. A clear formula applicable to this problem could not be found. The important factors in this connection were the alteration of the air frame weight, which was very much dependent upon the surface temperatures, and finally the resulting gain in the ballistic range.

75. The determination of the surface temperatures was not possible through an integrable formula but instead required time-consuming

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multiple stage calculations in tabular form. However, to do this, the ballistic path dimensions were necessary and these in turn presupposed knowledge of the design dimensions. The ballistic path values, however, could be determined also only by multiple stage tubular calculations and this was very time consuming.

76. On top of all this, there was some uncertainty concerning the views on the launching. If the ratio of motor thrust to the take-off weight became increasingly smaller, then the missile would have increasingly slower acceleration. This could cause difficulties when lifting the missile off the launching platform, if the motor thrust were not activated sufficiently rapidly and at its full magnitude. Furthermore, greater difficulties could be expected in windy, squally weather. Because of these numerous uncertainties, it was deemed inadvisable at the time to go far below two in regard to the ratio of motor thrust to launching weight. [redacted] the ratio for the R-10 was somewhere around 1.75.

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77. Using the design of the central section as described above, it was possible to stow more fuel in the central section of the missile while using the same length and diameter as the A-4. In addition, it was possible to increase the fuel volume further by lengthening the fuel container further without materially increasing the weight of the missile.

78. Without at first basically clarifying all the questions and problems outlined and thus obtaining an optimum ratio, the work proceeded as follows: The fuel quantity was simply increased to the point where the demanded range could be obtained with sufficient fuel reserve. This theoretical reserve was deemed necessary because of the many uncertainties and imponderables.

79. In this connection, it should be pointed out that the assumed absolute motor thrust also was increased somewhat as compared to the A-4. This increase in thrust was achieved by means of a slight increase in the combustion chamber pressure. Combustion tests of this kind with an A-4 combustion chamber were made in Germany. During these tests, [redacted] motor thrusts of 36-38 metric tons were obtained on test stands without difficulties.

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#### Weight Economies

80. Modification in the air frame design alone would hardly have been sufficient to increase the range had not weight economies on many other parts been made also. All motor parts were re-examined with respect to their importance and when possible subjected to weight economies.

81. The controls, inclusive of radio, constituted a large part of the weight of the A-4. The type and size of the A-4 equipment made it necessary to house the equipment in the forward part of the missile. This so-called "missile-rack" (Gaermetetraeger) added not only a considerable amount of weight, but also occupied a great deal of space which resulted in a loss of fuel storage space. Added to this was the lack of safety resulting from the required access panels, for the connecting points could easily be the cause of "air dispersers" (Luftzerleger).

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82. On the basis of many theoretical studies, as well as model path studies (Bahn/modelluntersuchungen), a new radar process was developed, based solely on the gyroscope (Kreisel) and radio. Important for the missile's accuracy is the exact control in relation to speed and exact positioning in space as regards to the ascending part of the flight path up to the moment of propellant cut-off. Theoretically, the new unit was to diminish considerably the possibility of target deviation. Also, it was no longer necessary to put these units in a particular space; instead, they could be added to the tail as a supplement. The gain in respect to weight economy was thus doubly great.

83. In each of the four tail units of the A-4 was an external control vane. Two of these were dispensed with, as they were found superfluous according to the views of the controls section.

84. A saving in weight was also accomplished in the propulsion unit. In the A-4, the turbine was driven by means of super-heated steam which was generated by the so-called "T" and "Z" fuel. As is well-known, the turbine drove the two centrifugal pumps needed for the production of the injection pressure for the alcohol and the liquid oxygen. These fuels were stored in containers which had to be very heavy to withstand the steam pressure. This generation of pressure in the containers was started by means of compressed air which was stored in high pressure cylinders, which were also by no means light.

85. In the R-10, a new development was provided which took the gas necessary for the actuation of the turbine directly from the motor. This gas, which was far too hot, was cooled sufficiently by an alcohol injection in order to prevent damage to the turbine blades. Such an installation had a fuel consumption of approximately the same magnitude as the "T" and "Z" fuel used in the A-4. However, the weight of the parts in the modified design was much less. Attempts at gas extraction for the propulsion of the turbine were made just prior to my departure from the Soviet Union and were found to be feasible. The gas extraction method saved not only weight, but also space in the tail, which in turn resulted in weight savings in the tail and thrust frame by shortening the frame correspondingly. Compressed air was still necessary for the starting of the turbine since the gas extraction would be possible only with the motor ignited.

#### Decreasing Residual Fuel

86. It would be of little use to economize on the weight of the missile, the propulsion unit, and other mechanisms if considerable quantities of residual fuels would remain in the tanks, fuel lines, etc. The residual fuel quantities enter the ballistic calculations just as adversely as the structural weights and service loads. A minor alteration of the alcohol and oxygen mixture is of little consequence to the thrust. It is highly undesirable to have a residue of one fuel while the other has been completely exhausted. This residual fuel can no longer be used in combustion and only raises the weight of the missile.

87. Consequently, efforts were made to determine as accurately as possible the optimum mixture ratio. A special auxiliary regulator unit, which from time to time would measure the liquid quantities

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and then automatically regulate the mixture ratio anew, would be most complex in design and also raise the weight additionally. The various members of the staff could not agree on such a regulator unit for the R-10 and instead settled for a calibrated diaphragm (Geeichte Blenden) which was to be mounted in the fuel lines. Thus, the solution, as regards the R-10, called for refined filling measurement of the two fuels coupled with the calibrated diaphragms which were to assure accurate fuel transmission.

88. In addition, by shortening all fuel lines, as well as by skillfully placing the quick acting fuel cut-off gate valve (Brennstoff-schnellschluessventil), the fuel in the lines could be kept as near to the minimum as possible. [redacted] the over-all residual fuel quantity that entered into the calculations was of the order of 200 kg.

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#### Warhead Separation

89. In the A-4 there was no separation in flight between the warhead and the remainder of the missile. The whole missile thus not only had to withstand the strain of the ascending part of the flight, but also the much greater strain encountered during the descending part of the flight.

90. The well-known difficulties of pressure head and boundary layer temperature rise during descent, somersaulting, added weight, disintegration, etc., associated with the A-4 flight path became greater with the required increase of performance of the R-10. The separation of the relatively small warhead from the body of the R-10 missile became mandatory since no other reasonable technical design appeared possible to cope with the above problems.

91. The plans called for separation of the warhead immediately after the propellant cut-off of the missile. The separation could be accomplished in various ways. It was possible to utilize, for example, the existing difference in air resistance between the warhead and the remainder of the missile. Or it was possible to use a slightly pre-compressed spring. In both cases, an additional mounting between the warhead and the remainder of the missile would not be necessary, as the warhead would be pressed on the missile while on the launching platform and held firm on the missile during the acceleration. The basic design of the warhead has been discussed previously.

#### Multi-Stage Design

92. With the possible structural modification, weight economies, and separation procedure, it appeared that the range and load requirements of the R-10 could be met and so the possibility of a multi-stage design with its many design difficulties was found to be an unnecessary method of solution of the basic R-10 problem. Even if it had been necessary to resort to such a design, many of the problems would have been insurmountable for the aero and thermodynamics departments because of the working handicaps under which they were placed.

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PHYSICAL CHARACTERISTICS AND LAYOUT

93. The information contained in this section deals with the physical characteristics and layout of the R-10 and its components. With the exception of the basic external dimensions of the A-4, all data are based solely on my memory and are, therefore, only approximate.

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Basic Data

94. Page 31 shows a general layout of the R-10 missile showing the basic external dimensions. The following data deal with the weights, capacity, and basic performance:

## a. Weight Allocation of the Empty Missile

	Warhead (Wood)	Warhead (Steel)
Warhead	1,150 kg	1,240 kg (approx. 980 kg. explosive)
Central Section	430 kg	430 kg
Tail w/Assembly & Steel Rudders	480 kg	480 kg
Propulsion Unit	700 kg	700 kg
Controls	<u>120 kg</u>	<u>120 kg</u>
Weight empty	2,860 kg	2,970 kg

## b. Fuels

A - Liquid oxygen	sp. gr. - 1.13
B - Alcohol + Water mixture	sp. gr. - 0.80 (approximately 70% alcohol, 30% water)
A - Fuel	9,060 kg 8,030 $\text{dm}^3$
B - Fuel	<u>6,540 kg</u> 7,350 $\text{dm}^3$
A & B Fuel	15,600 kg 15,380 $\text{dm}^3$

## c. Fuel Consumption Per Second

A - Fuel	<u>86.8 + 1*</u> = 87.8 kg = 58.1%
B - Fuel	<u>59.2 + 4**</u> = <u>63.2 kg</u> = 41.9%
A & B Fuel	146.0 + 5 = 151.0 kg = 100.0%

\* Additional Consumption for Venting the Container

\*\* Additional Consumption for Cooling the Gas Necessary  
for the Propulsion of the Turbine

## d. Motor Thrust (Without Jet Rudder Loss)

Thrust = Approximately 32,000  $\pm$  2,000 kg

The plus or minus 2,000 kg thrust was originally intended to be regulated for path control. However, the regulation was found to be too difficult and so cut-off was controlled according to the thrust output. The specific thrust amounts to approximately 220 kg/sec per kg fuel.

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## e. Fuel Residues

At propellant cut-off the following approximate quantities would remain in the missile:

A - Fuel residue; in gaseous state in A-container approximately	80 kg
B - Fuel residue; in gaseous state in B-container approximately	7 kg
A + B Fuel Residue; in liquid state in container	83 kg
A + B Fuel Residue; in liquid state in fuel lines	<u>110</u> kg
Total Residue Fuel	280 kg

## f. Combustion Period

From the above data the maximum time of combustion would be:

$$t = \text{approx. } \frac{15,600 - 280}{151} = \text{approx. } 101 \text{ sec.}$$

## g. Launching Weight

From the empty weights and the fuel weight the launching weight becomes:

- $2,860 + 15,600 = 18,460$  kg (wood warhead model)
- $2,970 + 15,600 = 18,570$  kg (steel warhead model)

## h. Propellant Cut-Off Weights

From the net weights (empty) and the residual fuel weights, the following propellant cut-off weights become:

- $2,860 + 280 = 3,140$  kg (wood warhead model)
- $2,970 + 280 = 3,250$  kg (steel warhead model)

## i. Maximum Speeds at Propellant Cut-Off

$v$  = approximately 2,600 m/sec (wood warhead model)

$v$  = approximately 2,510 m/sec (steel warhead model)

## j. Maximum Range

$s$  = approximately 840 km (wood warhead model)

$s$  = approximately 790 km (steel warhead model)

Warhead

95. Page 33 shows a longitudinal cross section of the wooden model of the warhead, as well as several enlarged prints. According to the design, the apex of the missile (2) was to be of steel in preference to other materials for three reasons:

- The apex had to be heavy so that the center of gravity of the warhead could be drawn forward.
- The mechanical and thermal stresses were too great.
- The casing of the apex would be thin so as to keep the interior space as large as possible.

96. The mechanism to measure the distance from the ground and at a given height detonate the explosives had to be stored in the apex.

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A definite space and a weight of approximately 40 kg was set aside for this mechanism. The mounting (simply screwing the unit to the wooden part) was executed in such a manner to permit heat expansion.

97. A wall dimension of 10 mm for the apex was selected because of the center of gravity considerations and above all, because of heat penetration. The temperature was to be kept low because of the wood connection and the radio control and measuring instruments in the interior of the missile.
98. The actual outer shell (3) and (4) was to be wound with veneer strips of birch having a thickness of approximately 20 mm. The rib (10) in the rear stabilization casing, as well as the reinforcements for the forward and rear panels were of glued laminated wood. The details A, C, D, and E on page 33 present a view of these connections more clearly. As the glued seams possess poor tensile qualities they were secured additionally to the outer shell by means of wooden pegs distributed around the whole missile and glued. The wooden pegs are not shown in the drawing, nor are two covers which were placed between C & D. The outer shell was reinforced at these points by a glued frame so that no weakening could be experienced. The covers, screwed to the frame, were to be constructed also of 20 mm plywood.
99. The rear partition (6) was also of glued veneer strips. It was given a conic shape as a result of a compromise between an advantageous force transmission (arising out of the explosives during longitudinal acceleration) and the need for simple (at least not too complex) construction.
100. The forward partition (5) was also given a conic shape, but in this case the partition was to be of steel because of the longitudinal loads derived through the mounting of the warhead at the connection (12).
101. This connection (12) was to be of a type that could readily transmit all forces and on the other hand could permit simple separation of the two parts, i.e., the warhead from the rest of the missile, after propellant cut-off. A central fastening appeared most desirable. A mounting of the missile without bracing would cause unduly high local strain in the mounting ring (11) and also on the central section. Consequently, the warhead was to be connected at point (12) to the central section and subjected exactly to a calculated tension. This was to be done by means of a cup spring. This connection was to be automatically severed shortly after the propellant cut-off and the spring tension was to serve as an aid in separating the two parts.
102. Because of later findings, the connection was to be used only during transportation of the missile on the ground. In flight, however, the central fastening was to be discarded and the warhead was simply mounted on the ring (11) on top of the central section. Calculations showed that the warhead would not lift itself off the missile, even though no further fastenings were used. This was true, even for strong cross winds, gusts, etc.

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since the longitudinal force derived through acceleration would prevent a separation of the two parts. The separation of the warhead from the missile after the propellant cut-off (that is after the disappearance of the longitudinal acceleration) would be possible also without using additional devices. Details of the fastening point (12) are no longer sufficiently clear [redacted] to permit drawing a sketch.

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103. The explosive (7) was to be ejected into the casing in a liquid state. [redacted] no information regarding the type of explosive except that it would turn to liquid at approximately 70°C. and that in a solid state the explosive had sufficient density to serve as a perfect support for the outer skin.

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104. Page 35 shows a longitudinal cross section of the steel model of the warhead. Several points of interest are reproduced in a larger scale.

105. The apex (2) was to be made of steel. The information given above regarding the apex of the wooden model also applies here. In the area of the explosives (7) a 2-case structural design (3) was necessary. A brief discussion concerning the development of this structural design and the problems that pertain was given previously.

106. The studs (14), which are welded into the outer shell, are spaced at approximately 40 mm intervals around the circumference. These studs serve to prop the outer skin during the latter's expansion in circular and longitudinal directions along the wedge-type rings (15). The tight connection of the inner shell (12) with the outer skin can be clearly seen from Detail A. The longitudinal forces arising from the explosives can be transmitted by this connecting point over the inner shell to the outer shell. The outer shell should remain considerably cooler in this part of the missile because of the wall dimensions in the area of this connection. Consequently, no compensatory expansion for radial expansion between inner and outer shell was provided at this point. Nor was a special insulation for the explosive provided, since a local melting could easily take place without affecting the performance and since the forward panel (5) provides sufficient static support. Danger to the explosive would arise only at skin temperatures over 300°C.

107. The stabilization casing (4) was reinforced against the outer pressure by means of the two ribs (10). The Details E and F show the shape of ribs. These simple shapes were selected primarily to permit heat flow between the outer skin and the ribs and not cause great temperature differences. From a static weight point of view, the ribs are not very advantageous.

108. The rear sealing panel was to be made of light metal and was conically shaped. Its purpose was to transmit the longitudinal forces arising out of the explosives to the inner shell.

#### Central Section

109. Page 37 shows the central section of the R-10 missile as well as several design details of interest. Included in the

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attached legend are the designations of some of the more important materials.

110. The principal material used was to be a weldable light metal (Soviet designation AM/3) with a strength equal to approximately 18 kg/mm<sup>2</sup> but with a very low elastic limit (approximately 8 kg/mm<sup>2</sup>). This low elastic limit stability was the determinant in the dimensioning of the parts. The material to be used in the cast parts had a somewhat similar composition as the primary material.

111. The point (2) and view B show the connection link for the warhead. At this point an initial tensile force of approximately 5,000 kg would be introduced. When strained (during transport on the ground) the load would be increased to more than 1,000 kg. The conic forward sealing panel (3) was well suited for the reception of this longitudinal force. The minimal gas pressure ( $p = 1 \pm 0.1$  atm) could be absorbed easily also. The forward panel could be unscrewed at the flange (4) as shown in Detail 6. These flanges also served for the reception of circumferential forces in the conic container part (5), which would arise as a result of the deflection of the forces coming from the conic panel. The cast rib (16) as shown in Detail 9 had a three-fold task, which was to:

- a. Absorb the circumferential forces acting on the alcohol container (7).
- b. Transmit the forces from the warhead to the central section of the missile.
- c. Absorb and correctly guide into the central section of the missile the two locally acting bearing forces resulting during transportation on the conveyor-carriage, and erection of the missile on the launching platform.

Point (8) shows the vent pipe for the alcohol tank (7).

112. The rib (9) in both tanks served as a form retainer and a reinforcement against indentations (local buckling). Because of internal pressures and temperature differences, the skin of the tank would expand radially at a different rate than a solid rib. Because of this the outer flange of the rib was slotted at intervals of 50 mm as shown in view E. The design then called for the flange to be spot welded near the end of the slotted flange. The flange attached to the skin in this manner could bend to conform to the skin expansion and thus prevent excessive strains between the skin and rib. This design was regarded only as a compromise solution.

113. The partition panel (10) separated the alcohol and oxygen tanks. Since the pressure in the oxygen tank would be greater (2.2 atm) than the pressure in the alcohol tank (approximately 1 atm), and since the correct design of such a panel became difficult, series of small experiments with a miniature panel (3:1) were performed. During these experiments the rupture pressures were obtained for various relationships of panel radius to panel wall thickness. As a result of these experiments a panel of relatively large wall thickness and a small curvature was called for. The tests also showed a strong static stability breakdown,

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with breakdown depending on the degree of precision use in the manufacture of the experimental pieces.

114. This fact was instrumental in causing the Soviet staff to seek another design solution retroactively. In this design the partition was inversely arched, so that the panel would receive tensile stresses primarily. However, in this design, compressive forces could not be prevented entirely, since the weight of the alcohol would be present during fueling prior to pressurizing the oxygen tank. In order to prevent excessive residues, using this design, it was necessary to shift the extraction pipe (17) and the heat insulation pipe (13) completely to the side. It would then be necessary to run the pipes at an angle through the oxygen container (12) and to the center of the rear panel.

This design had several disadvantages, namely:

- a. A certain amount of residues could not be prevented even with lateral extraction of the alcohol.
- b. A certain loss of container space could not be prevented.
- c. Along the outer skin the distance between the oxygen and alcohol would be decreased resulting in a large heat exchange between the two fuels.

In spite of these disadvantages, a series of sketches using this solution were prepared for the Soviets. This design is not shown here.

115. The venting pipe for the oxygen tank is shown as (11) on page 37. The tank itself is shown as (12). Point D (13) shows the reinforced (corrugated) heat insulation pipe. Because of the heat interchange it was not possible to separate the oxygen and alcohol tanks by means of a light metal wall. Not only would great quantities of heat be interchanged, but also the alcohol would freeze in the injection pipe (17) during the period the fully tanked and erected missile rested on the launching platform. In order to maintain a specially good heat insulation between the heat insulation pipe (13) and the alcohol extraction pipe (7), the circular space was to be filled with crumpled aluminum foil. Should the missile remain standing for long periods, a marked cooling of the alcohol in the extraction pipe (17) would cause a circulation flow. As a result of the difference in the specific weights of the fuel, circulation would occur between the extraction pipe (17) and also between the pipe lines and the motor casing in the tail section.

116. The corrugations in the heat insulation pipe (13) were found necessary for two reasons:

- a. The pipe (13) would be subject to external pressures. Such a pipe would have to be very thick were it not for the rib-like reinforcements. The corrugations increased considerably the moment of inertia and permitted the use of a smaller wall dimension. The intervals between the corrugation were obtained through stability calculations.
- b. The outer skin of the oxygen container would, particularly during the flight, have a different temperature than the protecting pipe. Consequently, changes in longitudinal

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dimensions could not be avoided and the partition panel (10) and the rear panel (18) would suffer deformations. In order to equalize these longitudinal dimension changes, the corrugations were found necessary.

117. Page 37 also shows one of the four connection channels (14) for the distribution of the locally introduced forces coming from the tail and motor and acting on the shell of the central section of the missile. All forces had to be introduced into the outer skin at the rear end of this sloped channel. The forward end of the channel and an intermediate point in the channel were supported by ribs. The forces coming from the motor connection fitting would be transmitted along the fitting (19) to the channel (14). When in tension, the forces would pass through the screwed connection point (21). When in compression, the motor fittings would rest against the end ring (15).

118. The sealing gasket (20) was placed between the end ring (15) and the fitting (19). The design shown in views E-F is not true. [redacted] the exact details without excessive loss of time, the design shown in views E-F is submitted only to show the general arrangement. Located in the rear panel (18) was a manhole cover plate which is not shown in this drawing.

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#### Tail and Tail Controls

119. On pages 39 and 41 are views of the tail section and tail controls. Several detailed exploded views and cross sections are presented in these pages. [Refer to appropriate legends for identification of points.] Care should be taken to distinguish between points in parenthesis and positions or stations in circles.

120. The outer tail cone (3) was to consist of four quarter shells which were to be connected to the four fins (2) by means of the bracket (16). The tail cone was to consist essentially of 10 ribs which supported the stringerless Dural cover. The Dural cover was to be 1 mm thick. The stresses arising out of transverse force and torsion were to be absorbed by the shell skin while the bending moments and the longitudinal forces were to be transmitted via the inner spar (9) and the connection joint (6), at Detail A, to the thrust frame and from there to the central section of the missile.

121. The four jet control vanes (5) and their motors were housed in a box-like steel framework (12). These girders were to transmit all forces to the fin ribs at stations ⑤ and ⑩ as well as to the skin.

122. The fins were to be composed of ribs at stations ⑤ and ⑩, the longitudinal member 10, and the latter's extension, the leading edge member (7).

123. The 1 mm Dural skin was stiffened additionally by non-continuous stringers. The two horizontal fins incorporated the rudders (4) which were to be driven by trimming motors (13). During launching the fins were required to transmit the great longi-

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tudinal forces originating at point (14) while the fully tanked missile rested on the launching platform.

124. The tail connection joint (6), at Detail A, was designed to transmit the total forces developed in the tail through the two bolts (18) to the fitting of the thrust frame. The longitudinal forces, as well as the longitudinal forces resulting from the bending moments, were to be transmitted through the leading edge members (7) and the inner spar (9). The transverse forces and the torsional moments on the other hand were to be transmitted to the fork (17) of the connection fitting (6) via the rib at station (1). At stations (1) and (2), the connection fitting (6) was to serve also as tail spar.

125. The rib at (1) at Details G & H, was designed to perform three essential tasks:

- It had to collect the dispersed thrust forces acting on the outer skin and to transmit them to the fork (17) of the connection fitting (6).
- At the same time it had to be sufficiently elastic so that it could, without too much force and without too great additional tension, join in the deformations which would be caused by the tightening of the connection of the central section of the missile. This tightening would occur at the moment that the liquid oxygen (-185°C) was injected. When the missile became fully tanked, the rib at (1) would lose its circular shape slightly. In order to achieve the required elasticity of the rib, it was necessary to divide the rib into four segments. The four segments were flexibly connected at the fork (17).
- As an end rib, it had to possess a suitable form so as to support the outer skin at the extremity.

126. The rib at (1) was designed as a U-channel closed by the outer skin. The rib at (2) was designed so as to absorb component forces coming from the leading edge member (7). The design height of the rib was limited by the thrust frame and other interior units. Consequently, a double U or I section was necessary at Details G & H.

127. The sectional views A-B and C-D show the method of connecting the steel quarter rib segments and fin ribs by means of the bracket (16). The transmission of the bending moments from the fin ribs to the spar was to be accomplished by means of the bracket (11). The inner spar (9) was not interrupted by this arrangement, except for a slot in the middle at view A - B.

128. The design of the leading edge member and longitudinal member, as well as the connection between the two parts, is shown in Detail B. The remaining views are sufficiently clear to show the design of those members [redacted] well enough to reproduce.

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#### Propulsion Unit and Venting

129. On page 42 is a schematic diagram of the propulsion unit and the fuel venting system. An exact drawing was not attempted [redacted]

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regulate the pressure in the B-container (2) at  $1.0 \pm 0.1$  atm.

135. A very brief starting procedure of the propulsion unit is presented as follows:

- a. The turbine would be brought to the required speed quickly by means of compressed air from an external source. The A-fuel main cut-off valve would be opened and by means of a primer composition the B-fuel would gain entry in the chamber. Simultaneously, an ignition between the A and B fuel would be effected. The quickly increasing motor pressure would permit the turbine (5) to function on the motor's exhaust gas. The rising missile would free itself from all launching instruments and servicing lines through break couplings.
- b. Rocket motor shut-off was to be accomplished by means of a quick action remote control system.  the cut-off valve (12) was to be jammed by means of a quick-acting explosive powder charge.

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136. On page 44 is a sketch of the thrust frame. The attached legend for the diagram contains information regarding material specifications. The thrust frame had the task of transmitting the forces from the motor (3) and the forces from the tail shell and the fin connection (10) into the central section (2). It also had to support the turbine pump mechanism (4), which in turn braced the cross piece (6). The thrust frame consisted of four longitudinal members (7), the cross piece (6), and the diagonal pieces (8). A bracing between the motor (3) and the cross piece (6) was not possible for lack of space. In order to prevent an excessive bending strain on the thrust frame because of transverse forces, the motor flange was attached to the rib end of the tail shell. The tail shell would be better suited for the transmission of the transverse loads. This would be more accurate, since during flight the rocket motor forces generally act in an opposite direction to the tail air load. How much was questionable and so this condition introduced another unknown factor.

137. The structural design of the attachment (9) is shown in Detail A. During the filling of the A-container the attachment points (9) would contract due to excessive cooling. This effect would cause additional forces and moments to bear on the thrust frame. Because of this an austenitic steel was selected for this part. At very low temperatures, this steel should not become brittle and should maintain a high notch impact strength.

#### CONCLUSION

138. The development of the R-10 (which had many other interim designations, such as G-1, G-10, etc.) was carried out during a period ranging from the summer of 1946 until the spring of 1950. During this time many diverse development facets were considered and numerous drafts were made of individual items. In this report, the final stage of the R-10 was discussed. A chronological description including a stage by stage review of the development work, the problems that were encountered in each

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since the propulsion unit was not materially changed over that of the A-4. The method of pumping the fuels, the venting, and the starting procedures were changed and the presented schematic should be sufficient to clarify these points.

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130. The gas to be extracted from the combustion chamber at point (8) would have a pressure and temperature approximately the same as that within the chamber, namely 22 atm. and 3,000°C. In order to reduce the temperature of the gas to approximately 500°C so as not to endanger the turbine, the gas was to be cooled by means of a stream of alcohol flowing around the extraction pipe and by injecting a small amount of alcohol into the gases. The cooling alcohol flowing between the motor walls would have a slightly higher pressure than the motor gases. Therefore, the injection through suitable bore holes should not cause great difficulties. Finding a suitable location and the designing of parts concerned was very problematic. When the design work on the R-10 had been completed, a long series of experiments were carried out to test systematically the gas extraction principal. The small test stands on the Island were used [redacted] the results of [redacted] the tests were regarded as satisfactory. 25X1

131. The gas cooled in the above fashion would then flow through line (9) to the turbine (5). Here part of its energy would be transferred into mechanical energy. The waste gas flowing through pipe (10) and escaping into atmosphere would be utilized in the form of thrust by means of the nozzles at the end of the line.

132. On the same axis as the turbine were the two turbine pumps. The B-fuel pump is shown as (6) and the A-fuel pump as (7) in the sketch. These turbine pumps would raise the A and B fuel to a pressure of approximately 25 atm.

133. The fuel was to flow from the A-container (3) through the line (11), the union (29) and the cut-off valve (12) into the turbine pump (7). From there it was to flow through the pressure lines (13) into the injectors located along the head of the motor (14). A small quantity of A-fuel would flow from the pressure lines (13) through the line (15) into the heat exchanger (16). Separation (i.e. heat extracted from the alcohol) would take place and the flow would continue through the venting line (17), the pressure-relief valve (17), and the bellows union (24) and finally into the A-fuel container (3). The pressure-relief valve (18) was to regulate the pressure in the A-fuel container at  $2.1 \pm 0.1$  atm.

134. The B-fuel was to flow from the B-container (2) through the extraction pipe (19) and the spring bellows (24), into the B-fuel turbine pump (6). From there, it was to flow through the heat exchanger (16), the pressure line (or compressed air line) (20) over the distributor ring (21) between the double motor jacket, through the motor (4), and finally injected through the motor head into the motor. The B-fuel flow is obvious. The gas used for the venting of the B-container (2) was to be taken from the gas feeding line (9). The pressure would be greatly reduced by the pressure-relief valve (22) which was to

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stage and the modifications that were made from day to day, would have been too time consuming and was not attempted.

139. The reason for the long period of development, and the many different development drafts can be explained by the following facts:

- a. The personnel assigned to the development work were essentially inexperienced and had to acquaint themselves with the missile field.
- b. The work and reports of the scientists and engineers during the course of the development period repeatedly offered new insights which in turn led to changes and new comparative drafts.
- c. The forcible recruitment contributed a great deal to retarding the work.
- d. A very rigid and formal development and planning system seriously curbed the development work. The Germans were required to submit a pre-draft project, a draft project, a sketch project, and a work project according to schedule. This method resulted in a great deal of lost time because of the many reports and sketches submitted, which to some extent were similar in content, yet were seldom thorough in execution because of the time element.

140. After 1950, some work continued which was of general importance to the missile. This dealt primarily with theoretical and experimental work in the field of controls, radio guidance and gas extraction for the propulsion of the turbine. All these projects which continued [redacted] were not an integral part of the R-10, but could nevertheless be associated or useful to the R-10.

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141. The R-10 design as finally submitted would undoubtedly cause difficulties. Many channels were explored, but the lack of experimental facilities did not permit the perfection of the missile. The structural testing of the many changes of the shell had to be dispensed with and the capacity improvement could not be justified. From the point of construction alone, many difficulties should be encountered in welding of the central section and particularly in welding the rear panel and end ring.

142. [redacted] the overall design of the missile must be looked upon as obsolescent. The A-4 outer contours and the old A-4 motor would result in a construction which would be altogether too complicated and too heavy. The high ratio between motor thrust and weight does not permit an optimum exploitation of the range. The speed in the denser air belt would be too great, resulting in excessive heating of the missile, which in turn affects the weight of the missile. The ultimate effect is a decrease in range. In all these considerations, the assumption was made that the method for the determination of surface temperatures, as developed by Dr. ALBRING, was correct. In view of insufficient experimental testing some insecurity existed in that regard. As the question of surface temperatures is of cardinal importance in some structural parts, a fundamental error in the calculation of the surface temperature would have

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great influence on the structural design. The inflexible development and planning scheme in the USSR was one of the main reasons for not making changes in the contours of the missile. It was impossible to interrupt a planned and initiated project and to replace it with a new and unplanned project.

143. The question of prime importance, "What was the ultimate disposition of the R-10?", cannot be answered

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[redacted] a few statements, which might serve as a guide. They are as follows:

- a. The development of the R-10 continued over a period of many years with great tenacity.
- b. During a scientific congress in Moscow [redacted] around Christmas of 1948) at which a few German supervisors gave a report concerning the R-10, no basic objections were raised by the Soviets. Shortly after, a financial premium was received by those associated with the project, which was assumed to signify approval of the project by the Soviet authorities.
- c. After this congress, the guiding principle was to carry out as many tests as were possible. After a few attempts, this bogged down, however, because of the lack of proper facilities.
- d. Inquiries by the Soviets regarding design continued to be received until the beginning of 1951.
- e. The generally continuing development in controls, guidance, and gas extraction indicated a great interest in these matters. A rational application of these results to the R-10 by Soviet engineers themselves was undoubtedly possible. Because of this, the actual Soviet plans remained hidden from the Germans.
- f. During May 1951, instructions were received to construct oscillation tables. Among these was a large oscillation table with dimensions to match exactly those of the A-4 and the R-10.

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144. [redacted] the caliber of the Soviet engineers and their ability to carry on the R-10 project. Those engineers at the Island [redacted] were only so-called second-and third-rate engineers [redacted] who were there primarily for administrative and monitoring purposes. They were hardly capable of carrying on a development program in the missile field. A few of the young officers at the Institute were quite capable, but were lacking in experience.

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145. [redacted] the first-rate engineers were not present for two reasons. The first reason was one of security. If a first rate engineer were present among the Germans, he would eventually reveal unconsciously other research and development secrets. As an example, a Soviet engineer, [redacted] appeared at the Institute in the fall of 1950 when work was started on the antiaircraft missile project. The engineer's assignment was to steer the thoughts of the Germans along certain paths. After the engineer had been among the Germans for approximately one month, it was obvious that he held a permanent

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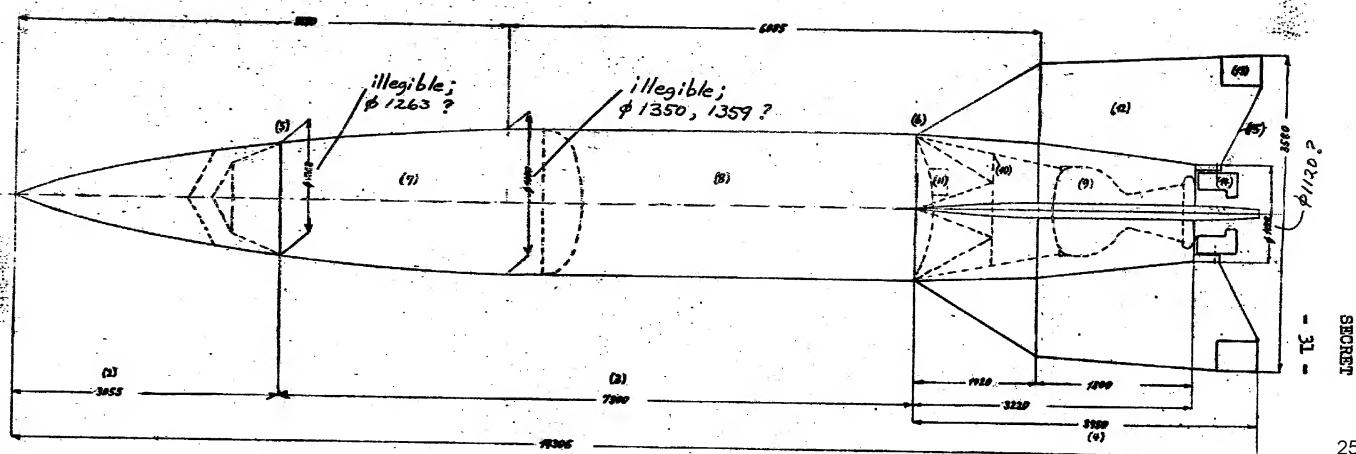
position in some other research and development institute engaged in work somewhat parallel to the antiaircraft project. Because of this leak the engineer was recalled and the Germans continued with no assistance.

146. [redacted] the second reason that first-rate engineers were not present was that the Soviets did not feel the activities at Gero domlya Island warranted the diversion of this type engineer from the true Soviet research and development programs. 25X1

147. Those engineers who were present at the Island were capable of criticism of unimportant points, but were not capable of criticizing the overall projects. In addition, they possessed no creative talent. An exception to this was a Soviet civilian engineer named BOSHKOV-SHUBINSKI (phonetic spelling) who was unofficially the chief engineer.

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NOTE: All dims in millimeters

## OVERALL VIEW of the R-10 MISSILE

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Centimeters

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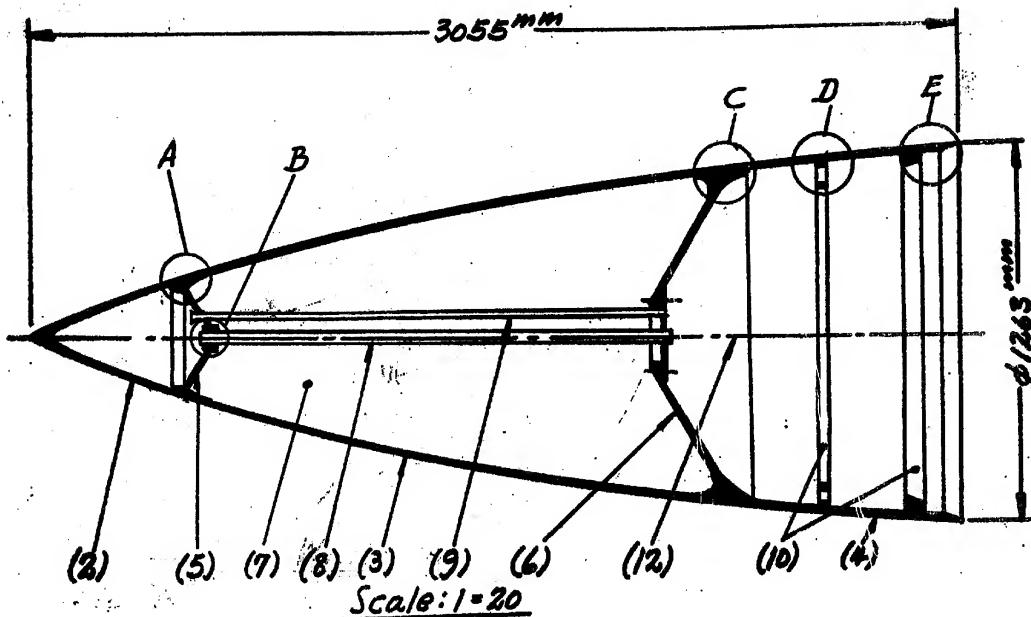
Legend (Overall View of the R-10 Missile)

- (1) No Point
- (2) Warhead
- (3) Central Section of the Missile
- (4) Tail and Control System
- (5) Forward Separation Point Between Warhead and Central Section
- (6) Rear Separation Point Between Central Section and Tail
- (7) B-Fuel Tank (Alcohol Tank)
- (8) A-Fuel Tank (Oxygen Tank)
- (9) Motor
- (10) Thrust Frame
- (11) Control Apparatus
- (12) Fin
- (13) Rudder
- (14) Jet Control Vanes
- (15) Antennae for Radio Control

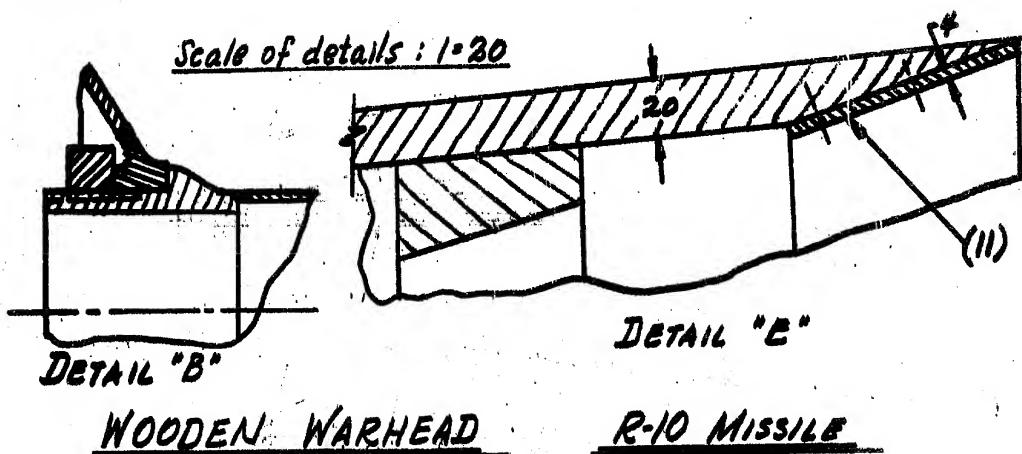
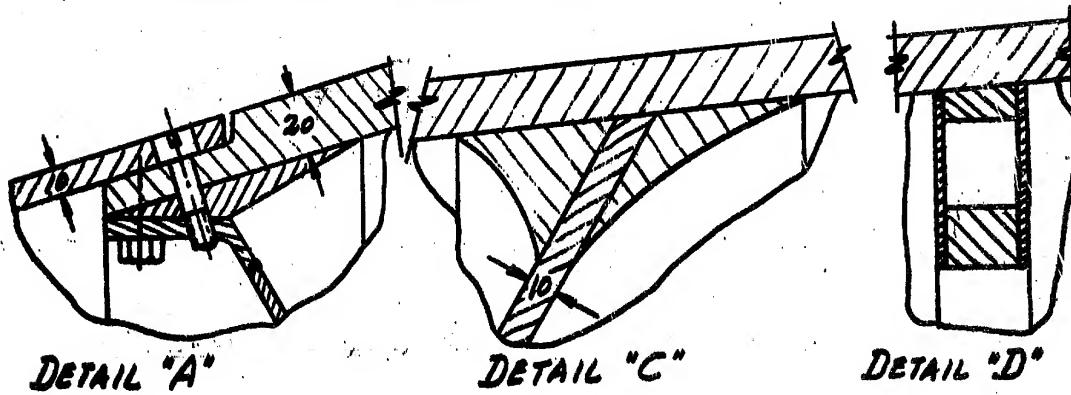
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Note: All dims given in millimeters



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## Legend

## (Wooden Warhead)

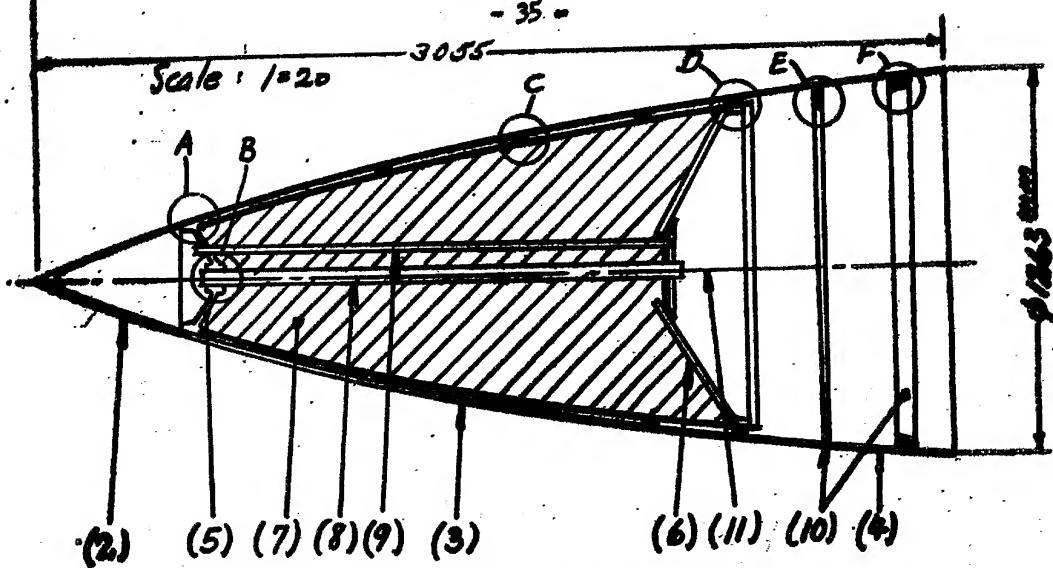
- (1) No Point
- (2) Steel Apex
- (3) Plywood Casing
- (4) Stabilizing Casing (made of plywood)
- (5) Forward Sealing Panel (Steel:  $30X\overline{CA}$ ;  $\sigma_B$  = approx.  $60 \text{ kg/mm}^2$ )
- (6) Rear Sealing Panel (Plywood)
- (7) Explosives
- (8) Connecting Pipe to the Forward Chamber (Steel:  $30X\overline{CA}$ ;  $\sigma_B$  = approx.  $60 \text{ kg/mm}^2$ )
- (9) Cable Pipe
- (10) Reinforcement Rib within the Stabilizing Casing made of Laminated Wood
- (11) Ring of Sheet Dural for Propping the Central Section of the Missile ( $\sigma_B$  = approx.  $38 \text{ kg/mm}^2$ )
- (12) Connection to the Central Section of Missile Not Shown

 $\sigma_B$  Indicates Tensile Strength

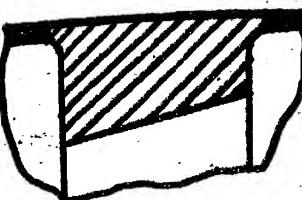
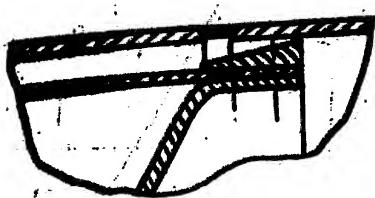
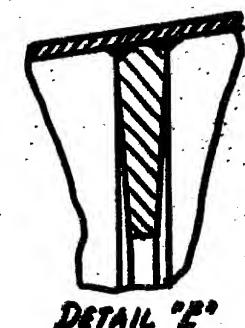
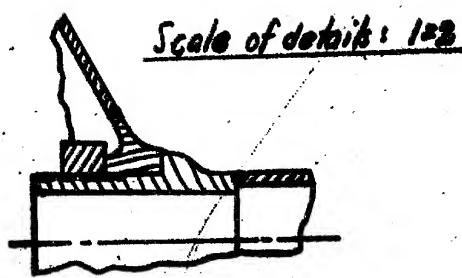
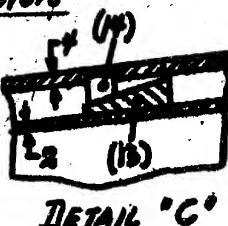
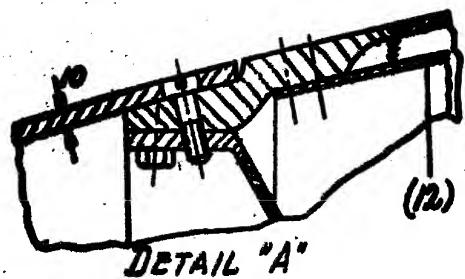
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NOTE: All dims given in millimeters



STEEL WARHEAD

R-10 MISSILE

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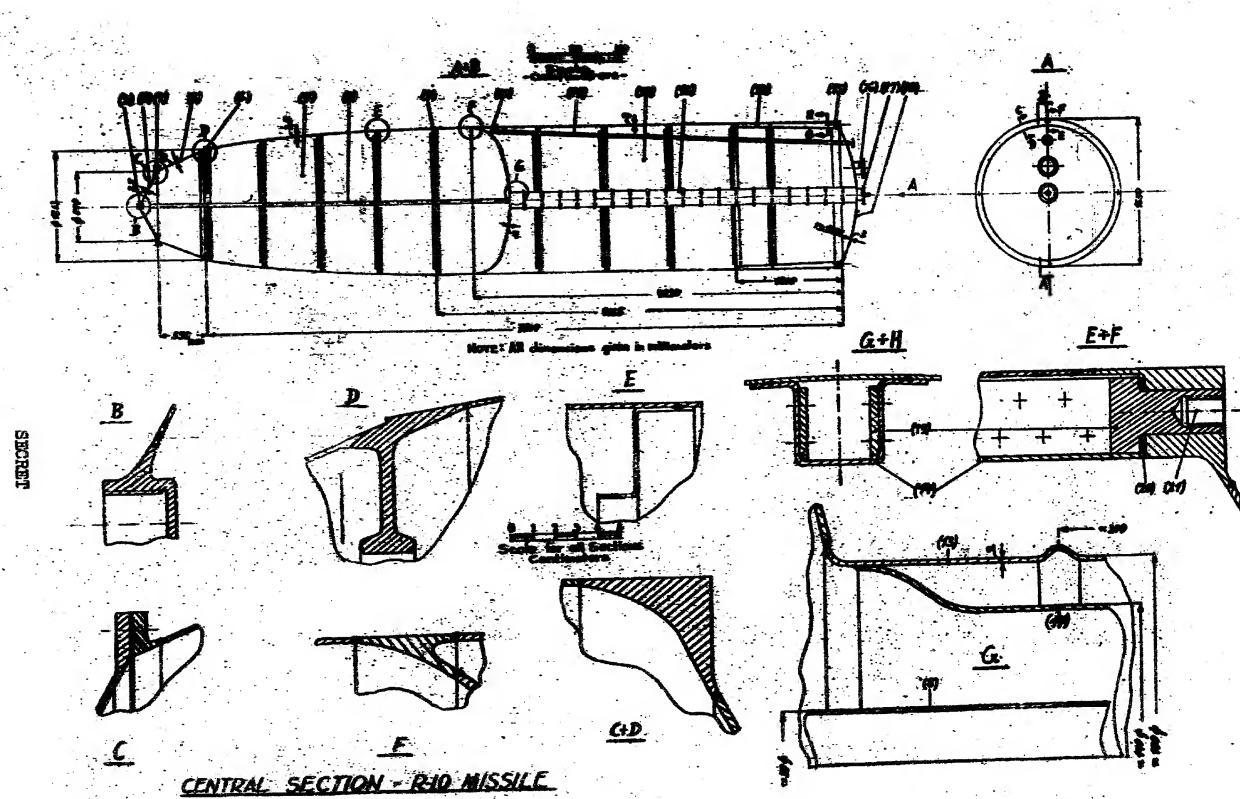
## Legend

## (Steel Warhead)

- (1) No Point
- (2) Steel Apex
- (3) Two-Shell (2-Case). Outer Skin in the Area of the Explosives (Outer Shell is of High temperature steel)
- (4) Stabilization Casing (91 T)
- (5) Forward Sealing Panel (Steel: 30X/74;  $\sigma_B$  = approx. 60 kg/mm<sup>2</sup>)
- (6) Rear Sealing Panel (Light Metal; AMT3;  $\sigma_B$  = approx. 18 kg/mm<sup>2</sup>)
- (7) Explosive
- (8) Connection Pipe Leading to the Forward Panel (Steel: 30X/74;  $\sigma_B$  = approx. 60 kg/mm<sup>2</sup>)
- (9) Cable Pipe
- (10) Reinforcement Rib in the Stabilization Casing (Steel:  $\sigma_B$  = approx. 60 kg/mm<sup>2</sup>)
- (11) Connection to the Central Section of Missile (not drawn)
- (12) Inner Casing in the Area of the Explosives (Light Metal: AMT3;  $\sigma_B$  = approx. 18 kg/mm<sup>2</sup>)
- (13) Riveted Wedge-Type Rings (Light Metal)
- (14) Welded Propping Pegs (of very highly alloyed nickel steel).

 $\sigma_B$  Indicates Tensile Strength

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## Legend

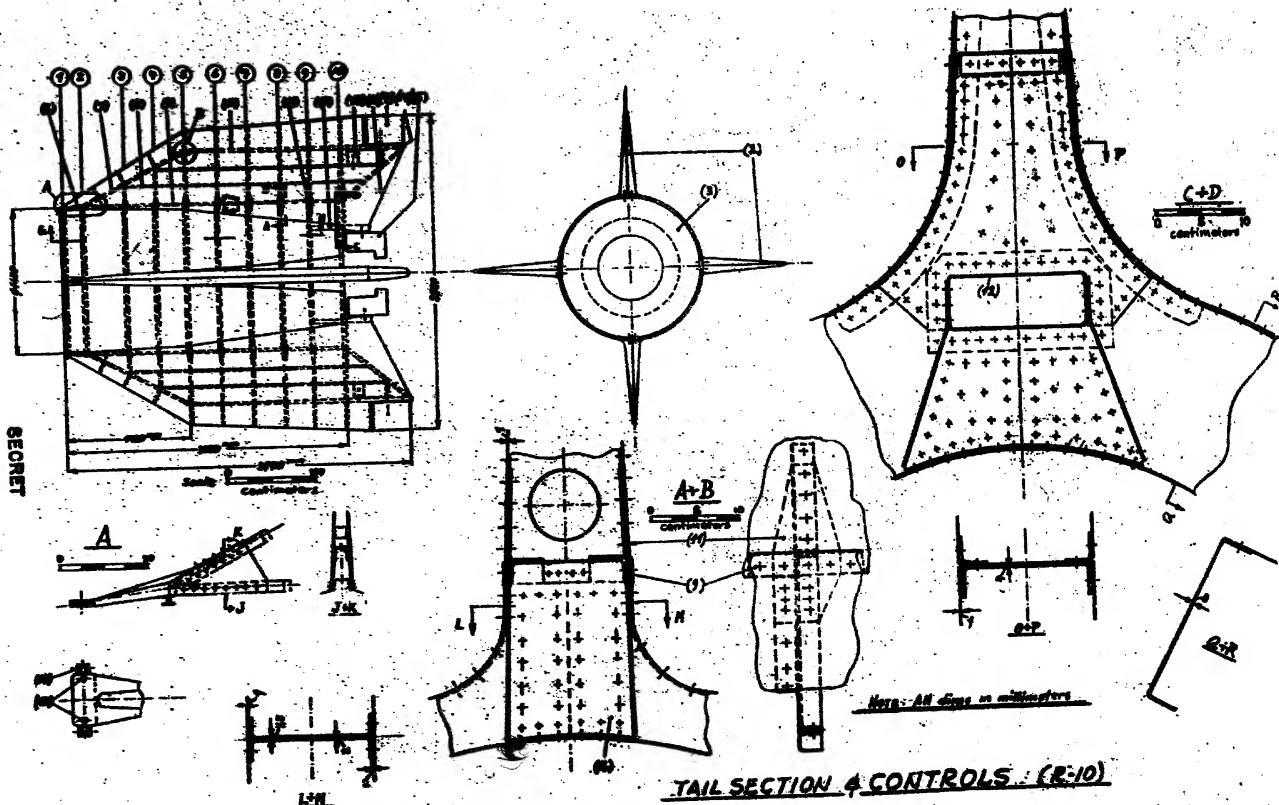
## (Missile Central Section)

- (1) No Point
- (2) Warhead Connection (under pre-tension)
- (3) Forward Sealing Panel (AM/3;  $\sigma_B$  = approx. 18 kg/mm<sup>2</sup>)
- (4) Forward Sealing Panel Flange (Cast Light Metal  $\sigma_B$  = approx. 16 kg/mm<sup>2</sup>)
- (5) Conic Container Section (AM/3;  $\sigma_B$  = approx. 18 kg/mm<sup>2</sup>)
- (6) Forward Rib (serves to prop the warhead and the missile during transportation ( $\sigma_B$  = approx. 16 kg/mm<sup>2</sup>))
- (7) B-Fuel Container (Alcohol) (AM/3;  $\sigma_B$  = approx. 18 kg/mm<sup>2</sup>)
- (8) B-Container Gas Feeding Pipe
- (9) Shape Retaining Rib (AM/3;  $\sigma_B$  = approx. 18 kg/mm<sup>2</sup>)
- (10) Partition (AM/3;  $\sigma_B$  = approx. 18 kg/mm<sup>2</sup>)
- (11) A-Container Gas Feeding Pipe
- (12) A-Fuel Container ( $O_2$ ) (AM/3;  $\sigma_B$  = approx. 18 kg/mm<sup>2</sup>)
- (13) Reinforced (corrugated) Insulated Pipe
- (14) Connection Channel (central section - tail) (AM/3;  $\sigma_B$  = approx. 18 kg/mm<sup>2</sup>) (Dural  $\sigma_B$  = approx. 38 kg/mm<sup>2</sup>)
- (15) Cast Light Metal:  $\sigma_B$  = approx. 16 kg/mm<sup>2</sup>
- (16) A-Fuel Extraction Nozzle
- (17) B-Fuel Extraction Pipe (AM/3;  $\sigma_B$  = approx. 18 kg/mm<sup>2</sup>)
- (18) Rear Panel (AM/3;  $\sigma_B$  = approx. 18 kg/mm<sup>2</sup>)
- (19) Connection Fitting (Dural  $\sigma_B$  = approx. 42 kg/mm<sup>2</sup>)
- (20) Sealing Gasket
- (21) Threaded Hole

$\sigma_B$  Indicates Tensile Strength

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## Legend

- (1) No Point
- (2) Tail Section
- (3) Fins (Skin: Dural  $\sigma_B$  = approx. 38 kg/mm<sup>2</sup>)
- (4) Tail Cone Shell (Skin: Dural  $\sigma_B$  = 38 kg/mm<sup>2</sup>)
- (5) Rudder (only 2 rudders for horizontal controls are provided)
- (6) Jet Vanes (4 vanes)
- (7) Tail Connection Fitting (Steel: 30X7CA;  $\sigma_B$  = approx. 60 kg/mm<sup>2</sup>)
- (8) Leading Edge Member ( Dural  $\sigma_B$  = approx. 38 kg/mm<sup>2</sup>)
- (9) Stringer (for the skin) Dural  $\sigma_B$  = approx. 38 kg/mm<sup>2</sup>)
- (10) Inner Spar ( Dural  $\sigma_B$  = approx. 38 kg/mm<sup>2</sup>)
- (11) Fin Longitudinal Member ( Dural  $\sigma_B$  = approx. 38 kg/mm<sup>2</sup>)
- (12) Bracket (steel) ( Dural  $\sigma_B$  = approx. 38 kg/mm<sup>2</sup>)
- (13) Frame Work for Jet Vanes and Mechanism (Steel: 30X7CA;  $\sigma_B$  = approx. 60 kg/mm<sup>2</sup>)
- (14) Rudder Drive Motor
- (15) Resting Point (semi-sphere shaped)
- (16) Trailing Edge Antenna Housing
- (17) Rib and Spar Bracket
- (18) Joining Fork for Rib Quarter Sections
- (19) Tail Connection Bolts (Tail to Thrust Frame) (Not indicated)
- (1) - (10) Stations Locating Fin and Tail Cone Ribs ( Dural  $\sigma_B$  = approx. 38 kg/mm<sup>2</sup>)

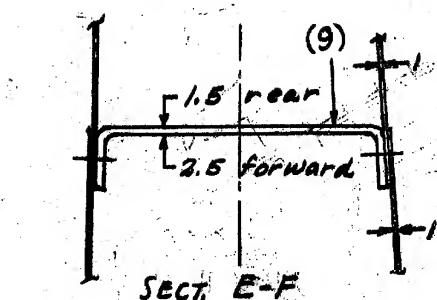
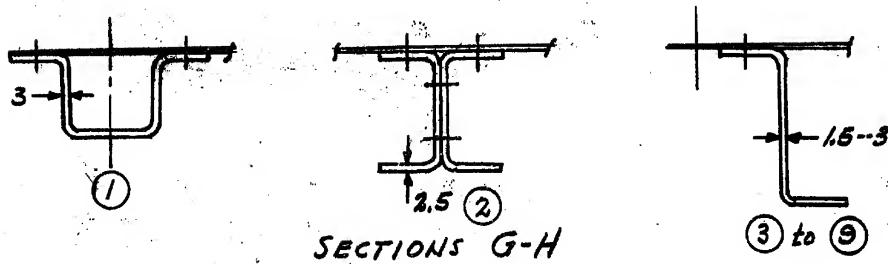
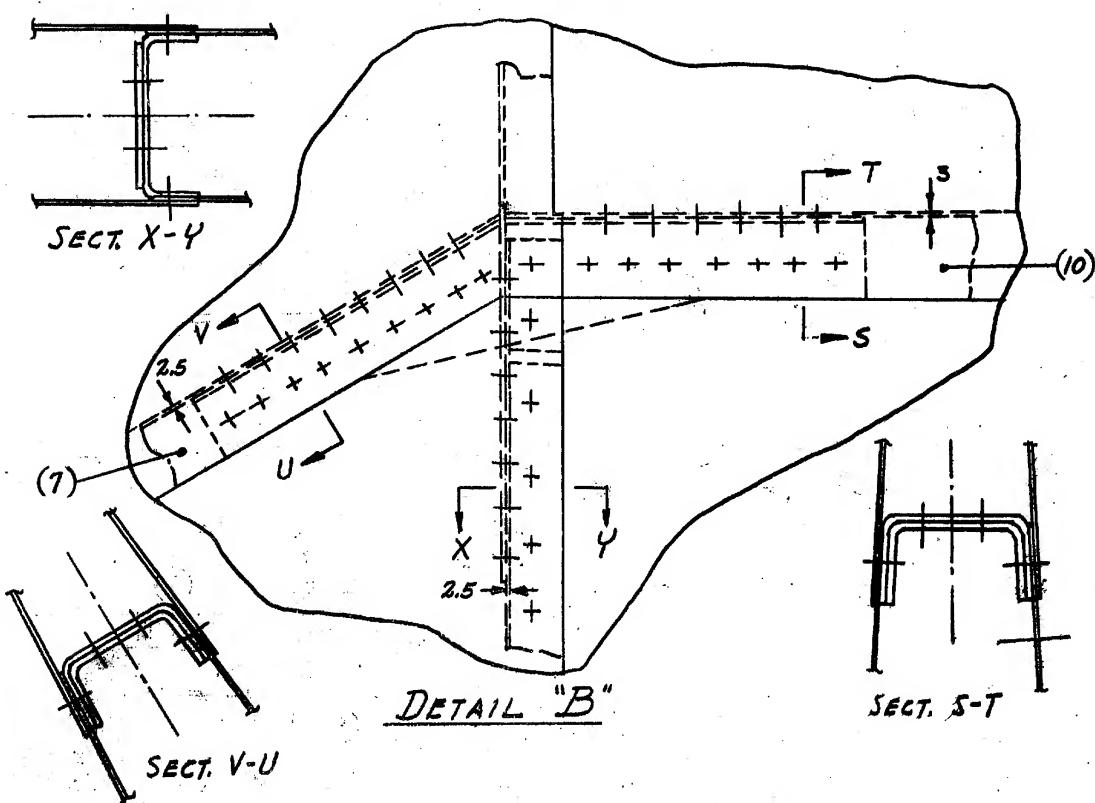
$\sigma_B$  Indicates Tensile Strength

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Note: All dims given in millimeters

DETAILS OF TAIL SECTION

R-10 MISSILE

Refer to Page 39

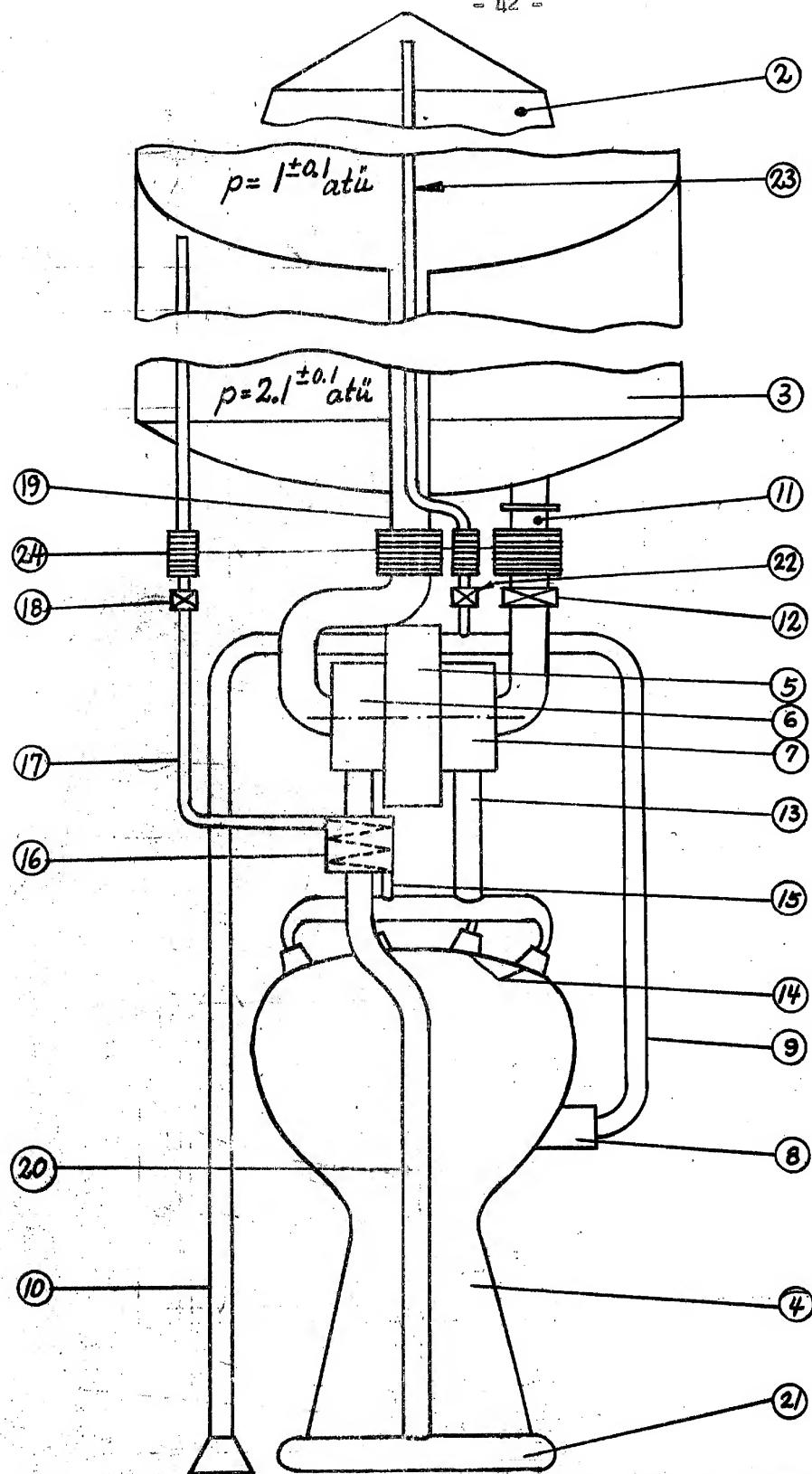
Scale 1=2.5

See legend, page 40

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Schematic dwg. of the PROPULSION UNIT &amp; VENTING SYSTEM

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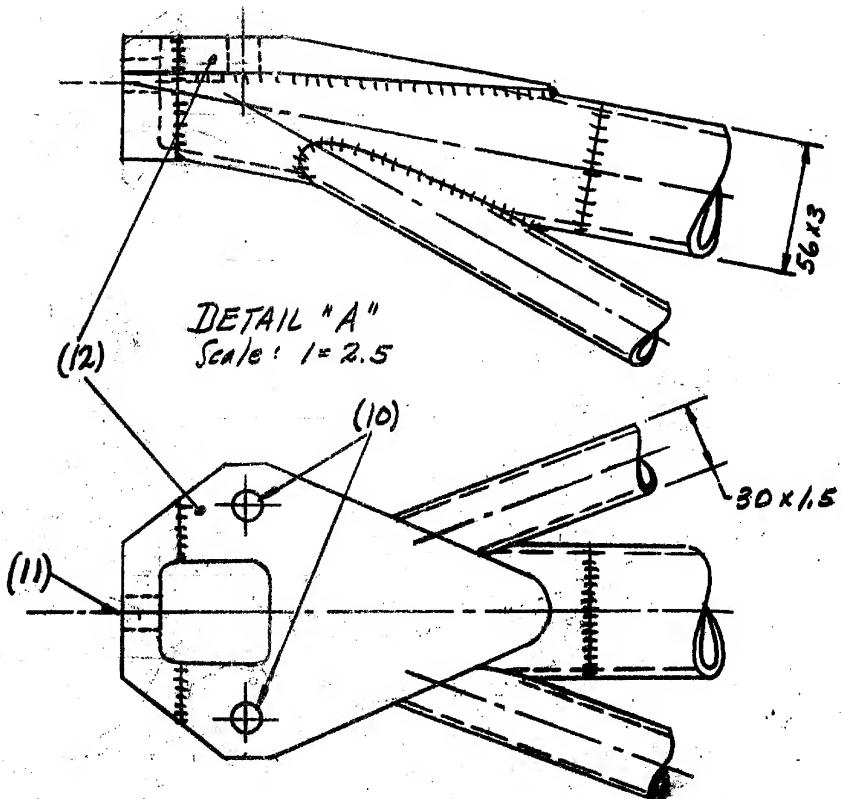
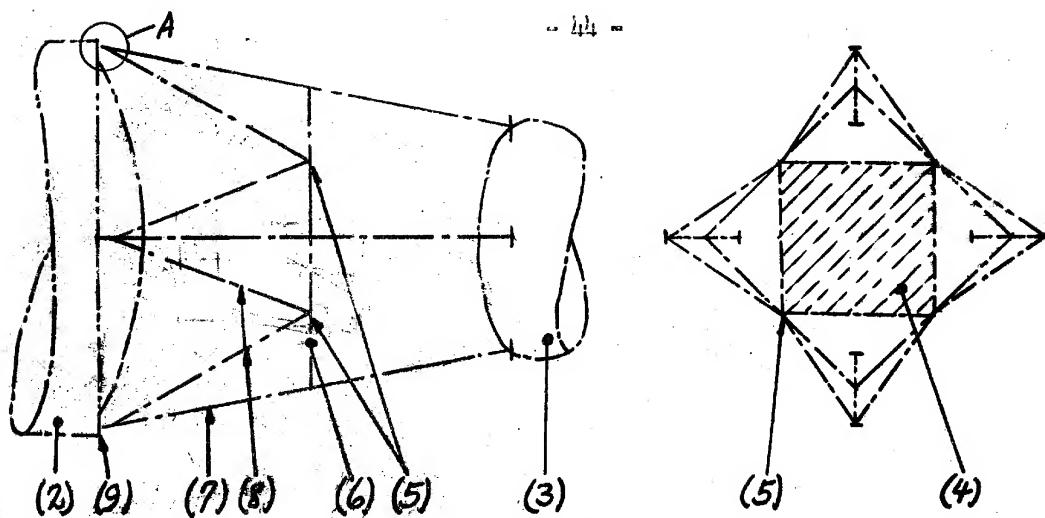
## Legend (Schematic Drawing of the Propulsion Unit and Venting System)

- (1) No Point
- (2) B-Fuel Container (Alcohol)
- (3) A-Fuel Container (Oxygen)
- (4) Motor
- (5) Turbine
- (6) B-Fuel Pump
- (7) A-Fuel Pump
- (8) Gas Extraction Fitting
- (9) Gas Line to the Turbine
- (10) Gas Line from the Turbine
- (11) A-Fuel Line from the A-Container
- (12) A-Fuel Main Cut-Off Valve
- (13) A-Fuel Pressure Line
- (14) A-Fuel Injectors
- (15) A-Fuel Line for Venting of the A-Container
- (16) Heat Exchanger for Vaporization of the A-Fuel
- (17) A-Fuel Vent Line
- (18) Cut-Off and Pressure Relief Valve for A-Venting ( $p = 2.1 \pm 0.1$  atm)
- (19) B-Fuel Line
- (20) B-Fuel Pressure Line
- (21) Distributor Ring for the B-Fuel
- (22) Cut-Off and Pressure Relief Valve for B-Venting ( $p = 1 \pm 0.1$  atm)
- (23) B-Vent Line
- (24) Metallic Bellow Unions to Compensate for Expansion and Vibration

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THRUST FRAME

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## Legend

- (1) Thrust Frame
- (2) Missile Central Section
- (3) Rocket Motor
- (4) Turbine Pump Installation
- (5) Attachment Points for (4)
- (6) Cross Piece (Braced through (4) (Steel: 30X7CA;  $\sigma_B$  = approx. 60 kg/mm<sup>2</sup>))
- (7) Longitudinal Members (Steel: 30X7CA;  $\sigma_B$  = approx. 60 kg/mm<sup>2</sup>)
- (8) Diagonals (Steel: 30X7CA;  $\sigma_B$  = approx. 60 kg/mm<sup>2</sup>)
- (9) Attachments between the Thrust Frame and the Central Section
- (10) Bolt Holes for Attachment of the Tail Shell
- (11) Hole for the Connection Screw (Thrust Frame and Central Section)
- (12) Bracket (Austenitic Steel A 1 T;  $\sigma_B$  = approx. 60 kg/mm<sup>2</sup>;  $\sigma$  approx. 25 kg/mm<sup>2</sup>)

 $\sigma_B$  Indicates Tensile Strength $\sigma$  Indicates Elastic Limit

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